PLANT COMMUNITIES OF SELECTED EMBAYMENTS ALONG THE MID- TO MID-UPPER OHIO RIVER FLOODPLAIN

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ABSTRACT

The vegetation was studied in embayment wetlands along the mid- to mid-upper Ohio River floodplain, Ohio and West Virginia. These wetlands were formed when the navigational pool elevation increased through the construction of the locks and dams for river navigation and low-lying areas adjacent to the Ohio River were inundated. The primary purpose of this study was to document and provide plant species and community information among embayment habitats. Five embayments were quantitatively sampled for woody and herbaceous species during summer and fall, of 1990 and 1991. Tree and shrub/sapling communities were evaluated through the use of relative important values. Herbaceous and aquatic communities were defined through the use of relative importance values, cluster analysis, indicator species analysis, and multi-response permutation procedure. A non-metric multi-dimensional scaling, an indirect ordination procedure, was also used to evaluate potential underlying environmental gradients. There were 257 species of vascular plants recorded from approximately 27 ha of embayment habitat. Embayment wetlands capture approximately 25 percent of the species that are common elements of the floodplain. More than half the number of species encountered across the sample area was restricted to one or two sites. This suggests that these wetlands have common elements at large broad scales with distinct elements at local scales. There were differences in herbaceous plant species, richness and diversity (*H'*) and composition among embayment sites ($P < 0.01$). Analyses of 497 vegetation plots and quadrats revealed 17 plant communities. There were five forest communities of *Acer saccharinum*, four *A. saccharinum* and one *Alnus serrulata* shrub/sapling communities. The herbaceous and aquatic plant communities were characterized by eight communities that were common to the region and four communities that were considered unique. Non-metric multi-dimensional scaling and multi-response permutation procedures results ($P < 0.01$) show that plant species were distributed according to embayment location, age and size and to a lesser extent according to species composition (non-native species, Coefficient of Conservatism, species richness and H') and wetland indicator status probability values. Our study shows that embayment wetlands hold species rich habitats and that more surveys (qualitative and quantitative) are needed to address questions that relate to biodiversity, nutrient cycling, and hydrogeomorphologic characterization.

RESUMEN

Se estudió la vegetación en pantanos de embahiamiento a lo largo de la llanura de inundación media y medio-superior de Río de Ohio, Ohio y Virginia Occidental. Estos pantanos se formaron cuando aumentó el nivel de la línea de navegación por la construcción de cierres y presas en el rio y se inundaron las áreas bajas adyacentes al Río de Ohio. El propósito primario de este estudio fue documentar y proporcionar información de especies de plantas y comunidades de hábitats de embahiamiento, un hábitat único de pantano. Se muestrearon cuantitativamente cinco embahiamientos para especies leñosas y herbáceas durante el verano y otoño, de 1990 y 1991. Se evaluaron las comunidades arbóreas y arbustivas mediante el uso de valores de importancia relativa. Las comunidades herbáceas y acuáticas se definieron mediante valores de importancia relativa, análisis cluster, análisis de especies indicadoras, y de procedimiento de permutación multi-respuesta. Se utilizó también una escala multi-dimensional no-métrica y un procedimiento de ordenación indirecta para evaluar los gradientes ambientales, fundamentales y potenciales. Había 257 especies de plantas vasculares registradas en los aproximadamente 27 ha de hábitat de embahiamiento. Los pantanos de embahiamiento tienen aproximadamente el 25 por ciento de las especies que son frecuentes en las tierras inundadas. Más de la mitad del número de especies encontradas en el área de muestreo estaban restringidas a uno o dos sitios. Esto sugiere que estos pantanos tienen elementos comunes a gran escala con distintos elementos a escala local. Encontramos diferencias en la riqueza y diversidad (*H'*) de las especies herbáceas, y la composición en los lugares de embahiamiento (P <0,01). Los análisis de 497 parcelas de vegetación y cuadrados revelaron 17 comunidades vegetales. Había cinco comunidades de bosque de *Acer saccharinum*, junto con cuatro de *A. saccharinum* y una de *Alnus serrulata* arbustivas. Las comunidades herbáceas y acuáticas se caracterizaron por pertenecer a ocho comunidades que fueron comunes a la región y cuatro comunidades que fueron considerados únicas. Los resultados de los cálculos de la escala multi-dimensional no-métrica y de permutaciónes multi-respuesta ($P < 0{,}01$) muestran que las especies estaban distribuidas según la ubicación del embahiamiento, la edad y el tamaño, y en menor medida por la composición en especies (especies exóticas, Coeficiente de Conservación, riqueza de especies y *H'*) y valores de probabilidad de estatus como indicadoras

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de pantanos. Nuestro estudio muestra que los pantanos de embahiamiento tienen la especie hábitats ricos en especies y que más estudios cuantitativos resolverán dudas relativas a la biodiversidad, al ciclo de nutrientes, y la caracterización de hidrogeomorfológica.

INTRODUCTION

The importance of wetlands to society has been recently, within the last 30 years, brought to the attention of policy makers (Hyberg & Riley 2009; Junk & Wantzen 2004; Mitsch et al. 2000). In 1974, the U.S. Fish and Wildlife Service (FWS) established the National Wetlands Inventory (NWI) Program (Tiner 2009). The charge of this program was to conduct a nationwide inventory of wetlands in order to provide FWS biologists with information on the distribution of wetlands for wetland conservation efforts (Tiner 2009). In 1986, the Federal Government mandated, through the Emergency Wetlands Resources Act, that the FWS complete mapping and digitizing of wetlands data for the Nation, and to distribute and archive the data (Dahl et al. 2009). The NWI program developed a wetland classification system (Cowardin et al. 1979) which is the current federal standard of the USFWS and the Federal Geographic Data Committee (Tiner 2009). The original purpose of the National Wetlands Inventory program was to map, on a large scale, our nations' wetlands. The current products of the program are a wetlands geospatial database that can be used to generate maps and statistics about the status of the Nation's wetlands and the other products include national wetlands status and trends reports (Tiner 2009).

Overall the NWI program has been an incredible success but there are limitations. According to the 2009 NWI Status Report, the most frequent complaint about the program is that the data are too old for many applications and that the NWI data should be updated more frequently (Tiner 2009). Further, there is the issue of incomplete data, only 61% of the nation's wetlands have been mapped and entire wetland areas and wetland margins were or are not detected with the remote sensing that took place in the 1970s and 1980s (Cowardin & Golet 1995).

The regulation of rivers and natural water-ways for flood control, agriculture and urban development, and river navigation affects the hydrological connectivity or flood pulse of the river with floodplain and riparian wetland ecosystems (King et al. 2009; Reid and Brooks 2000). Specifically, the flood pulse concept (Junk et al. 1989) states that the dynamic nature of the hydro-geomorphological condition is the primary force that is responsible for the existence, productivity, and interactions of biota in river-floodplain systems (Junk et al. 1989; Junk 1999; Junk & Wantzen 2004).

The Ohio River is formed by the confluence of the Allegheny and Monongahela Rivers at Pittsburgh, Pennsylvania. Navigation on these rivers has evolved from the use of bark and dugout canoes of the Native Americans to mass river transportation by barges. In its original condition, navigation along the Ohio River was difficult and hazardous due to natural fluctuations of the river throughout the year (US Army Corps of Engineers 1979). The first river modernization project, started in 1955, replaced nineteen moveable locks and dams. The purpose of the modernization project was to convert river navigation from a local commerce to an 'interstate highway' (Johnson 1992). The hydrology of the river has changed from an open channel to a series of 'reservoirs' between dams. The water depth increased profoundly in low-lying areas adjacent to the river. These changes in the river channel, flow and navigation water pool elevation resulted in the loss of many wetlands but it also created wetlands or embayments. Originally these areas were periodically inundated throughout the growing season but after the modernization projects they were permanently flooded. Embayments are most often formed along permanent or intermittent stream channels.

Although the U. S. Fish and Wildlife Service (2002) identified approximately 2225 ha of undisturbed embayments within its' planning area of the Ohio River Island Wildlife Refuge and the agency recognizes that embayments are significant habitats for fish, mussels, amphibians and reptiles, waterfowl and mammals. Embayment plant communities have not been inventoried except for a few isolated studies performed through agents of the U.S. Army Corps of Engineers. Koryak (1978) examined a recently formed embayment after the completion of the Hannibal Locks and Dam. The potential for embayment aquatic and emergent plant community development is high and there is strong evidence to indicate that embayments in older navigational pools support productive plant communities with high biological diversity (Koryak 1978). There is little known about embayment plant communities along the Ohio River floodplain other than large scale wetland mapping by the National Wetlands Inventory Program. The purpose of this study was to survey and identify embayment plant communities, assess potential gradients, and to provide a local and regional characterization of embayment that typically occur along the mid to mid-upper Ohio River floodplain, River.

METHODS AND MATERIALS

Study Site Description

Potential study sites were selected from U.S.G.S. and U.S. Army Corps of Engineers navigational topographical maps (U.S. Army Corps of Engineers 1966, 1978), Ohio River Navigational Charts (U.S. Army Corps of Engineers 1989), and color aerial photographs (obtained from the U.S. Army Corps of Engineers, Huntington, WV). These resources were used to assess wetland size, type, associated habitat, disturbance levels, and ease of access (Ely 1993). Each study site was delineated from the surrounding uplands based on hydrological conditions, vegetation, soils, and slope.

The study sites (embayments) are located in the Greenup and Gallipolis or R.C. Byrd navigational pools (Fig. 1) between river km 434 and 549. The 115 km stretch of the Ohio River occurs between Gallipolis Ohio and Greenup Kentucky. The original Gallipolis Locks and Dam was a part of the 46 movable lock and dam series and maintained a maximum navigational water depth of 2.75 m (Shows & Wooley 1989). This was replaced with non-removable roller-gates that increased navigational pool elevation by 5.8 m (Johnson 1992; Jones 1914). Sites selected in this navigation pool were at least fifty-three years old in 1991 and include Chickamauga Creek (river kilometer 434, 8.3 ha), Crab Creek (river kilometer 444, 2.1 ha) and Teen's Run (river kilometer 449, 4.0 ha).

The current Greenup Locks and Dam replaced four of the original 46 dams and it was operational in 1962 (Johnson 1992). This increased the navigational depth more than six meters (Jones 1914; US Army Corps of Engineers 1979). Sites located in the Greenup navigational pool include Franklin's or Chandler's Run (river kilometer 549, 3.2 ha), and Ginat's Run (river kilometer 546, 9.3 ha), (Fig. 1) and these sites were at least twenty-nine years old at the time of the study.

The study area lies within the mixed mesophytic forest of the Allegheny Plateau (Braun 1950) and are located within the Western Allegheny Plateau of the Eastern Temperate Forest Ecoregions of North America (Alan et al. 2007a, 2007b). Three of the five study sites are located within the Monongahela Transition Zone and the other two sites occur in the Ohio-Kentucky Carboniferous Plateaus with elevations ranging from 157 to 165 m above sea level. Mixed mesophytic and mixed oak forests were the original forest of the Western Allegheny Plateau (Alan et al. 2007a, 2007b). Today, urban, residential, and agriculture development dominate the floodplains. The average January and June temperatures are 1.6°C and 24°C, respectively (Alan et al. 2007a, 2007b). Braun (1950) described the bottomland hardwood forest of the mixed mesophytic region as an *Acer saccharinum* L. (silver maple) and *Populus deltoides* Bartram ex Marsh. (eastern cottonwood) community with contributions of *Salix* spp., *Platanus occidentalis* L. (sycamore), *Liquidambar styraciflua* L. (sweetgum), and *Betula nigra* L. (river birch). It is believed that these five study sites represent the features of a typical embayment for this region of the Ohio River floodplain.

Sampling

Each embayment site was visited monthly during summer and fall of 1990 and 1991. The vegetation at each embayment site was divided into three layers or strata: trees (overstory), sapling and shrub (understory), and herbaceous (groundcover). Submerged aquatic plants were sampled with the herbaceous cover because they often integrate. In addition, trees, woody saplings and shrubs, and ground cover species were treated as separate quantitative studies. Sampling plots in the tree and shrub and sapling layers were randomly placed while a stratified random sampling of herbaceous plots was used (see below). Original identification procedures followed Gleason and Cronquist (1991), Strausbaugh and Core (1978), Cusick and Siblerhorn

Fig. 1. Map of study site locations along the mid- to mid-upper Ohio River floodplain, Gallia County (Chickamauga Creek) and Scioto County (Chandler's Run, Ginat's Run and Teen's Run) Ohio and Mason County (Crab Creek) West Virginia.

(1977), Britton and Brown (1970), but the current nomenclature follows the Flora of North America North of Mexico (Flora of North America Editorial Committee 1993+). Voucher plant specimens were collected and are deposited in the Marshall University Herbarium, Huntington, WV (MUHW; Ely 1993).

Trees in this study were defined as woody plants that were equal to or greater than 8.0 cm in diameter at breast height (1.4 m) or DBH. Trees were identified to species and DBH recorded to the nearest tenth of a centimeter. Saplings and shrubs were defined as woody plants less than 8.0 cm DBH but equal to or greater than 1.0 m tall. Their height was visually estimated to the nearest meter and recorded.

Herbaceous species were composed of herbaceous plants, woody plant seedlings less than 1.0 m tall, and species of woody vines. Woody plants that exceeded 1.0 m in height but were too dense and/or prostrate to record in the usual manner were also included. Such species included in this category were *Rosa palustris* Marsh. (swamp rose) and *Cornus amomum* Mill. (silky dogwood).

Herbaceous plot sampling occurred along two to five transect lines at each study site. The number and placement of transect lines depended on embayment size. For example, the larger sites were evaluated with four to five 100 m transect lines whereas smaller sites were evaluated with two. In general, transect lines reached from the edge of the wetland to open water. Plots measuring 100 m^2 were placed along each transect line. Eight 1 m^2 quadrats were randomly selected within each 100 m^2 plot. For each species, the percent cover values were visually estimated and recorded in each quadrat. Species area curves were established and used as a guide to obtain an adequate number of plots.

Data Analysis

Overstory, understory, and herbaceous communities were assessed through the calculation of relative importance values. The overstory DBH values were converted to basal area (BA) for each species. Density, frequency, BA (overstory), estimated height (understory) values were used in determining relative importance values. Relative importance values for herbaceous plant species was derived from relative frequency of occurrence and percent estimated cover values for each taxon.

Herbaceous species percent cover values were converted to a modified Daubenmire cover class scale (Daubenmire 1959). The midpoint values of each cover class were used in subsequent analyses. The seven cover classes were: 1: 0 to < 1%, 2: 1 to 4%, 3: 5 to 24%, 4: 25 to 49%, 5: 50 to 74%, 6: 75 to 94% and 7: 95 to 100%.

Herbaceous species diversity was evaluated using species richness, evenness (Pielou 1966) and Shannon-Weiner (Shannon 1948) indices. Index values were calculated based on a quadrat by quadrat basis and means and standard errors were calculated for each study site. Coefficient of Conservatism (Wilhelm & Ladd 1988) and wetland indicator status probability values (Reed 1988) were determined for each native species. Because the Coefficient of Conservatism values for the same species differed significantly ($P < 0.05$) between the states of Ohio and West Virginia, average values among the two states were used in order to make the data comparable. Non-native species were also identified among embayment sites. The indices, WI, CC, cover values, non-native cover values were used to assess the uniqueness and similarities of each site and to identify potential gradients. In addition, herbaceous species and species composition among study sites were compared using Multi-Response Permutation Procedures (MRPP) and indicator species were calculated using Indicator Species Analysis (ISA).

Herbaceous species cover data were classified into groups using agglomerative hierarchical cluster analysis and potential gradients were identified with Non-metric Multidimensional Scaling, NMS, an indirect ordination procedure. In order to define groups, we calculated a Cluster Analysis with Sorensen's distance measure (Sorensen 1948) based on the midpoints of the Duabenmire cover class data using flexible beta with ß = -0.25 in the program PC-ORD (McCune & Mefford 1999). Although Soresen's distance measure has been under scrutiny (Legendre & Legendre 1998) for its' use with community data analysis, our justification for use is that it resulted in the least amount of chaining among sample plots with cluster analysis and the lowest stress with the NMS ordination (see below). Chaining is the phenomenon of the addition of single sample quadrats to existing groups that result in undefined clusters. Indicator species for each of the cluster analysis defined groups were identified using Indicator Species Analysis, ISA (see below). The wetland probability indicator status (Reed 1988), WI, was determined for each native species belonging to each group or community as defined by cluster analysis. The categories include Obligate+, Obligate, Obligate-, Facultative Wet+, Facultative Wet, Facultative Wet-, Facultative+ Facultative, Facultative-, Facultative Upland+, Facultative Upland, Facultative Upland- or Upland. In addition, habitat (aquatic, mudflat, or emergent) and dominant species height (tall, medium or short) were determined for each group.

An ISA was used to determine the statistically significant indicator species (as defined by indicator value or IV) in each cluster grouping. This procedure combines information on abundance and frequency data to determine the 'faithfullness' of a particular species to a particular group or cluster. Faithfulness can be defined as the constancy of presence or how likely a specific species will be found in a cluster group (McCune & Grace 2002). In order to explore the relationship of herbaceous species and sample data to potential environmental gradients we use Non-metric multi-dimensional scaling (NMS). Although direct measurement of environmental variables was not a part of this study, we used an indirect approach using Species Richness, Shannon-Wiener Diversity (*H'*), embayment age and river location (expressed in river kilometer), species cover (total and non-native), wetland indicator status probability values (Reed 1988) and Coefficient of Conservatism values (Wilhelm & Ladd 1988; Rentch & Anderson 2006; Andreas et al. 2004). Strengths of association between these values and the NMS axes scores were calculated using Kendall's Tau, τ, values (Zar 2010). Joint biplots were constructed from the ordination scores and τ values.

All NMS analyses were conducted using Sorensen's distance measure. Monte-Carlo tests were used to determine statistical significance of each NMS solution. The percent of variation represented and the coefficient of determination for each axis, the final stress value, and associated *P*-values are reported.

Cluster analysis, NMS, MRPP and ISA were performed using PC-ORD version 4.41 (McCune & Mefford 1999). An alpha (α) or significance level of 0.05 was used for NMS and ISA. A Bonferroni correction to the α-level (Sokal & Rohlf 1995) was made for the MRPP based on the number of embayment sites.

RESULTS

Species Composition

A total of 257 vascular plants species was encountered among study sites during the course of the study period; there were 3 fern and fern allies, 84 Monocots and 170 Dicots representing 77 families and 201 genera. The largest number of species occurred in the Poaceae (28, 10.85%), Cyperaceae (27, 10.47%), and Asteraceae (25, 9.69%). Polygonaceae (11, 4.26%) and Fabaceae (9, 3.49%) had a limited contribution to species numbers. The number of non-native species across sites was 40 (16.72%). The average Coefficient of Conservatism value was 3.51 (± 0.02).

The number of species encountered within and outside of sampling plots at each embayment site ranged from a low of 119 (Teen's Run) to a high of 157 (Ginat's Run). Ginat's and Teen's Run had the largest number woody species encountered in the tree (11 each) and sapling and shrub communities species (n = 13 and 14, respectively) during this study (Table 3).

Herbaceous species richness and diversity was significantly higher at Chickamauga Creek ($\bar{X}$ = 3.35±0.09) than other sites (Fig. 2i, ii). There were no differences in Species Richness among remaining embayments. Ginat's Run had a significantly higher diversity value ($\bar{X}$ = 1.10±0.06) than Teen's Run ($\bar{X}$ = 1.00±0.04), but there were no differences among the remaining embayments (Fig. 2ii). Although there were no differences in total cover between Chickamauga ($\bar{X}$ = 193.88±9.47) and Crab Creek ($\bar{X}$ = 176.94±9.09), both sites had higher values than the remaining study sites (Fig. 2iii). Coefficient of Conservatism was lowest at Chickamauga Creek ($\bar{X}$ = 3.35±0.09) while Crab Creek ($\bar{X}$ = 3.59±0.04) and Chandler's Run ($\bar{X}$ = 3.56±0.10) were the highest (Fig. 2iv). The mean wetland probability values among sites were highest at Crab Creek ($\bar{X}$ = 95.43±0.62) and Chandler's Run ($\bar{X}$ = 94.04±0.73) (Fig. 2v) while Chickamauga Creek ($\bar{X}$ = 84.49±1.16) was the lowest. Both Chandler's ($\bar{X}$ = 19.42±3.99) and Teen's Run ($\bar{X}$ = 18.13±3.28) had the highest non-native species cover (Fig. 3vi) and Ginat's Run ($\bar{X}$ = 0.46±0.20) had the lowest non-native.

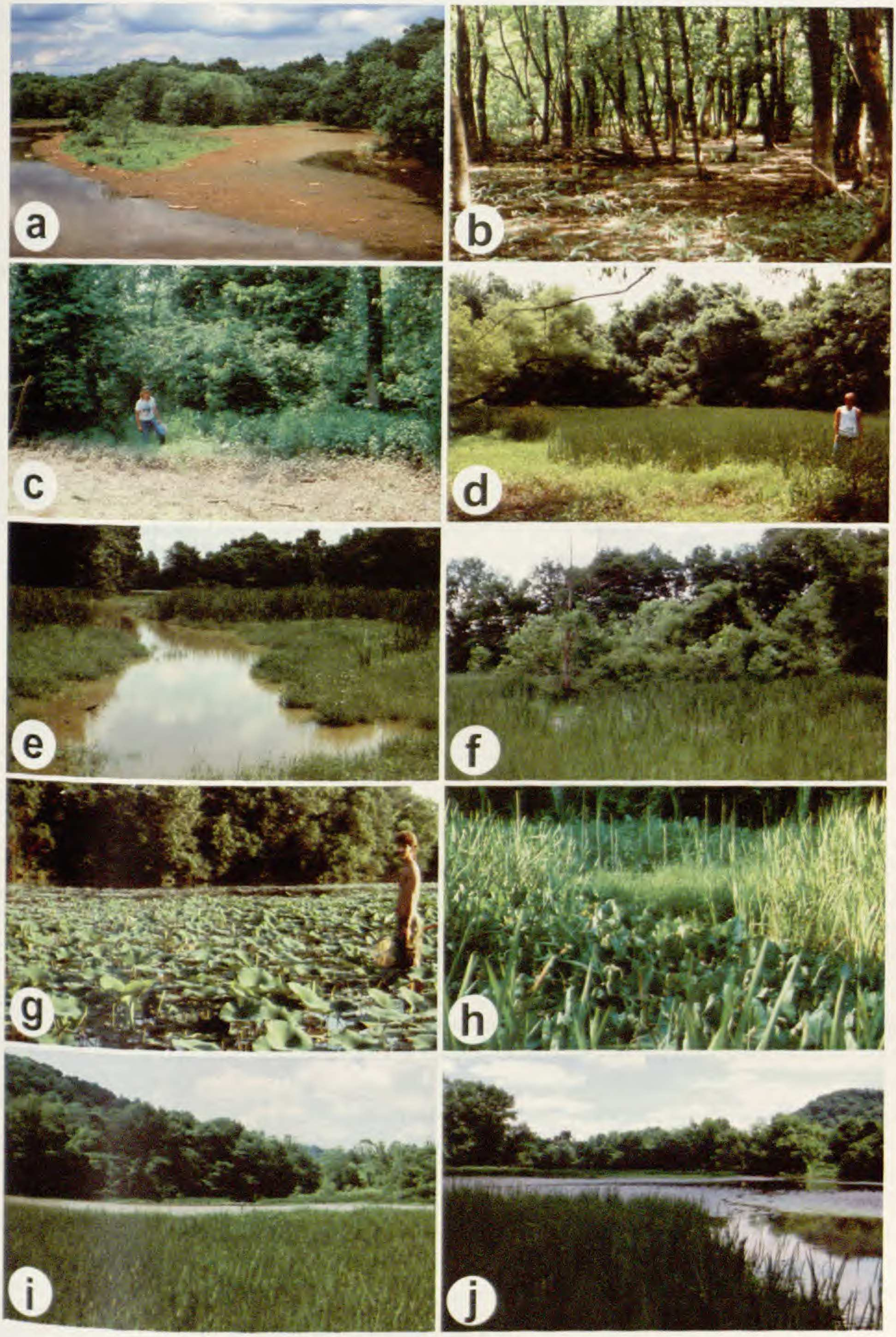

FIG. 2. Embayment wetland habitat types. Chickamauga Creek embayment during the spring (**a**) and *Acer saccharinum* bottomland hardwood forest (**b**); Crab Creek open oxbow, mid-summer (c) and early fall (**d**); Chandler's Run early summer (**e**,**f**); Ginat's Run *Nelumbo lutea* bed (**g**) and emergent marsh (**h**); and, Teen's Run early summer (**i**) and Autumn (**j**).

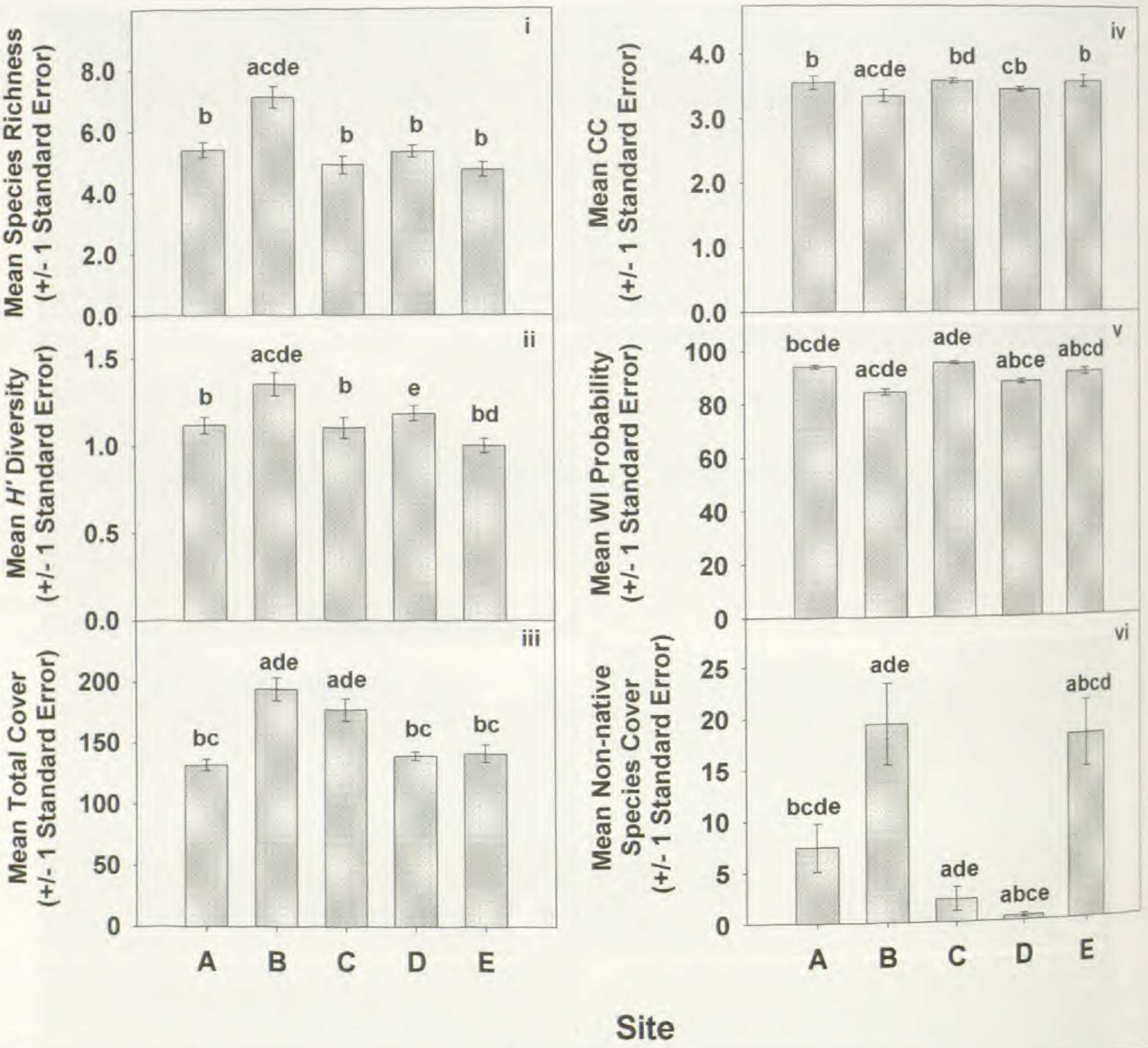

Fig. 3. Mean (± 1 standard error) species richness, diversity, species cover, Coefficient of Conservatism, Wetland Indicator Status probability values, and non-native species cover for Embayment sites along the mid- to mid-upper Ohio River floodplain. Different lower case letters indicate significant differences and A = Chandler's Run, B = Chickamauga Creek C = Crab Creek, D = Ginat's Run, and E = Teen's Run.

Regional Community Composition and Structure

The bottomland hard wood forest across the study area was dominated by *Acer saccharinum* with contributions of *Fraxinus pennsylvanicum* Marsh. (green ash), *Platanus occidentalis*, and *Salix nigra* Marsh. (black willow), and a variety of upland and wetland species (Table 1). The sapling layer consisted of *Acer saccharinum* and *Fraxinus pennsylvanicum* (Table 2) while the shrub layer was characterized by *Cephalanthus occidentalis* L. (common buttonbush), *Cornus amomum*, *Alnus serrulata* (Aiton) Willd. (hazel alder), and *Lindera benzoin* (L.) Blume (northern spicebush) (Table 2). All tree, sapling and shrub communities consisted of native elements of the region except for one individual of *Ligustrum vulgare* L. (European privet) occurred at Teen's Run. The herbaceous plant community consisted of *Sparganium eurycarpum* Engelm. (broadfruit bur-reed), *Leersia oryzoides* (L.) Sw. (rice cutgrass), *Sagittaria latifolia* Willd. (broadleaf arrowhead), *Persicaria sagittata* (L.) H. Gross (arrow-leaf tearthumb), and *P. punctata* (Ell.) Small (dotted smartweed) (Table 3). The floating aquatic community is characterized by *Lemna minor* L. (duckweed) , *Spirodela polyrrhiza* (L.) Schleiden (greater duckweed) and *Leersia oryzoides* while the submerged aquatic layer was comprised of *Myriophyllum spicatum* and *Najas minor* All. (water-nymph) with interspersed *Elodea nuttalli* (Planchon) St. John (free-flowered water-weed).

Table 1. Basal area (BA) and relative importance values (RIV) of the Tree strata among selected embayment sites and at the regional scale.

	Chickamauaga Creek		Crab Creek		Chandler's Run		Ginat's Run		Teen's Run		Regional	
Species	**BA**	**RIV**	**BA**	**RIV**	**BA**	**RIV**	**BA**	**RIV**	**BA**	**RIV**	**BA**	**RIV**
Acer negundo	1343.8	4.5	95.0	3.8	285.1	9.2	190.1	2.4	44.4	1.5	391.7	4.3
Acer saccharinum	81674.8	64.0	11217.8	48.7	42344.5	62.9	30819.3	39.5	15643.8	47.7	36340.0	52.5
Betula nigra							95.0	2.0			19.0	0.4
Carya laciniosa							1295.1	3.1			259.0	0.6
Fraxinus pennsylvanica	3721.2	7.5	2558.8	20.4	1333.6	7.0	9191.7	19.8	467.4	3.6	3454.5	11.7
Liquidambar styraciflua							3024.6	7.0			604.9	1.4
Nyssa sylvatica							95.0	2.0			19.0	0.4
Platanus occidentalis	7470.7	6.9	2503.0	15.1	1693.3	6.8	2325.6	7.0	4455.2	18.3	3689.6	10.8
Populus deltoides	804.3	2.1							59.4	1.4	172.7	0.7
Robinia pseudoacacia							1361.9	7.7	425.4	2.6	357.4	2.1
Salix nigra	11431.5	8.7	1349.3	8.3	2833.7	14.2	95.0	2.0	2104.5	11.9	3562.8	9.0
Ulmus rubra	665.2	6.3	95.0	3.8			3183.2	7.5	459.5	7.5	880.6	5.0
Cercis canadensis									22.2	1.3	4.4	0.3
Catalpa speciosa									103.8	2.9	20.8	0.6
Prunus serotina									59.4	1.4	11.9	0.3
Total:	107111.4	100.0	17819.0	100.0	48490.2	100.0	51676.5	100.0	23844.8	100.0	100.0	100.0

Local Community Composition and Structure

Tree, Sapling and Shrub and Herbaceous Communities.—The tree community at the site level reflected similarities in species composition and importance that was observed at the regional scale with subtle differences. Although all sites were dominated by *Acer saccharinum*, *Platanus occidentalis* was a subdominant at Crab Creek and both *P. occidentalis* and *Fraxinus pennsylvanicum* were also important at Teen's Run (Table 1).

The sapling and shrub communities varied more than the tree community among sites. *Acer saccharinum* was an important sapling and shrub species among all sites except for Ginat's Run. *Alnus serrulata* dominated the community at Ginat's Run and was a sub-dominant at Chandler's Run. *Fraxinus pennsylvanicum* dominated the sapling and shrub community at Crab Creek and was a subdominant at Chickamauga Creek (Table 2). *Cornus amomum* was dominant and subdominant at Teen's Run and Chickamauga Creek, respectively. *Lindera benzoin* was an important understory tree at Crab Creek. *Amorpha fruiticosa* L. (false indigo) was of minor importance at Chandler's Run (Table 2). Five communities were identified among embayment sites. Similar to the tree community, Ginat's and Teen's Run's the sapling and shrub community had the highest species represented among all sites, 13 and 14, respectively.

The MRPP for the testing of differences in herbaceous species cover and sample data were moderately to well defined among embayment sites ($T = -83.12$, δ = of 0.39, $A = 0.21$, $P < 0.01$). The herbaceous plant community consists of *Sparganium eurycarpum*, *Leersia oryzoides*, *Sagittaria latifolia*, *Persicaria sagittata*, and *Persicaria punctata* (Table 3). The floating aquatic community would be characterized by *Lemna minor* / *Spirodela polyrrhiza* while the submerged aquatic layer consisted of *Myriophyllum spicatum* and *Najas minor* that was interspersed with *Elodea nuttalli*. Relative importance and indicator values indicated that the herbaceous community was the most variable community at the site level. The emergent marsh community at Chickamauga Creek was characterized by *Persicaria punctata*, *Sagittaria latifolia*, *Commelina virginica* L. (dayflower), *Carex tribuloides* Wahlenb., *Leersia oryzoides*, and *Nelumbo nucifera* Gaertner, Crab Creek emergent herbaceous community was dominated by *Sparganium eurycarpum*, *Leersia oryzoides*, and *Sagittaria latifolia*. One floating and emergent plant community consisting of *Lemna minor* L. (lesser duckweed) / *Spirodela polyrrhiza* was found in an old oxbow channel at Crab Creek. Overall the herbaceous layer at Chandler's Run was characterized by a *Persicaria sagittata*, *Leersia oryzoides*, *Sparganium eurycarpum*, *Hibiscus moscheutos* L. (crimsoneyed rosemallow), *Persicaria punctata*, and *Sagittaria latifolia* emergent community (Table 3). Ginat's Run's emergent marsh consisted of *Leersia oryzoides*, *Sagittaria latifolia*, *Sparganium eurycarpum*, *Persicaria sagittata*, *Onoclea* sensibilis L. (sensitive fern), and *Juncus effusus* L. (soft rush). *Sparganium eurycarpum*, *Sagittaria latifolia*, and *Iris pseudacorus* L. (yellow flag) characterized Teen's Run herbaceous community.

Classification of Herbaceous Plant Communities

The results of the cluster analysis and indicator species analysis (Fig. 4) show twelve defined groups with 22% of the information (Wishart 1969) remaining at that level. The result of the Indicator Species Analysis (ISA) was significant ($P < 0.05$). ISA indicator species values or IV are reported along with the Relative Importance Values (RIV) for each defined group or community (Table 4). The wetland indicator status, height, embayment site, and number of quadrats, n, for each community are also included.

There were two obligate+ aquatic communities consisting of a submerged community and a short emergent community. The submerged community was dominated by *Najas minor* and *Myriophyllum spicatum* and these species were indicators (Table 4, Fig. 4-community G). This community was only observed at Chandler's Run (n = 8). The short emergent community (Table 4, Fig. 4, community H) with a dominant and indicator species of *Nelumbo lutea* was interspersed with the submerged aquatic *Myriophyllum spicatum*. Similar to the former community, this community was observed only at one embayment, Ginat's Run (n = 6).

There were three obligate- wetland communities that consisted of one medium and two tall emergent communities. The medium emergent community was dominated by *Persicaria punctata* and *P. hydropiperoides* (Michx.) Small (swamp smartweed) and these species were the top indicators for that community (Table 4, Fig. 4, community A). This community was distributed at Chandler's Run (n = 13), Chickamauga Creek (n =

TABLE 2. Density (D) per hectare and relative importance values (RIV) of the sapling and shrub strata among selected embayment sites and at the regional scale.

	Chickamauaga Creek		Crab Creek		Chandler's Run		Ginat's Run		Teen's Run		Regional	
Species	**D**	**RIV**	**D**	**RIV**	**D**	**RIV**	**D**	**RIV**	**D**	**RIV**	**D**	**RIV**
Acer negundo	1.4	3.0	34.3	6.4	3.4	8.5	3.8	2.5	142.4	4.9	37.1	5.1
Acer saccharinum	101.9	25.6	128.7	15.9	58.2	48.1	20.0	3.6	988.5	21.6	259.5	22.9
Alnus serrulata	8.3	3.7			34.2	26.0	704.1	67.5			149.3	19.4
Amorpha fruticosa					3.4	7.6	10.0	1.7			2.7	1.9
Asimina triloba			17.2	4.1							3.4	0.8
Betula nigra			8.6	2.7			2.5	1.3			2.2	0.8
Carya laciniosa									67.0	2.8	13.4	0.6
Cephalanthus occidentalis	246.4	20.8							1.2	1.2	49.5	4.4
Cornus amomum	6.9	13.5					11.3	2.8	1097.4	21.7	223.1	7.6
Fraxinus pennsylvanica	59.2	14.5	369.1	33.9			11.3	1.6	75.4	4.0	103.0	10.8
Juglans nigra									8.4	0.8	1.7	0.2
Ligustrum vulgare									100.5	4.3	20.1	0.9
Lindera benzoin			240.3	16.1					259.7	5.5	100.0	4.3
Platanus occidentalis	2.8	3.3	25.8	6.6			1.3	1.2	125.7	5.6	31.1	3.4
Robinia pseudoacacia							37.6	4.0	8.4	0.8	9.2	1.0
Salix nigra	4.1	9.2	34.3	6.7	6.9	9.8	17.5	5.7	1218.8	20.5	256.3	10.4
Sambucus nigra ssp. *canadensis*							3.8	1.3			0.8	0.3
Sassafras albidum							5.0	2.5	8.4	0.8	2.7	0.7
Tilia americana var. *heterophylla*	1.4	2.3									0.3	0.5
Ulmus rubra	2.8	3.1	51.5	7.6			3.8	4.3	150.8	5.6	41.8	4.1
Total:	435.0	100.0	909.7	100.0	106.1	100.0	831.8	100.0	4252.4	100.0	1307.0	100.0

TABLE 3. Relative indicator values (IV) and importance values (RIV) of groundcover among embayment sites.

	Chandler's Run		Chickamauga Creek		Crab Creek		Ginat's Run		Teen's Run		Regional
Species	IV	RIV	IV	RIV	IV	RIV	IV	RIV	IV	RIV	RIV
Apios americana			14.4	0.30							0.00
Bidens frondosa					20.5	0.43					0.43
Bidens tripartita					35.7	0.89					0.89
Boehmeria cylindrica			18.8	0.75		0.48				0.30	0.78
Carex lurida										0.42	0.42
Carex tribuloides			35	1.36						0.44	0.44
Carex vulpinoidea									11.5	0.35	0.35
Commelina communis			21.5	0.39							0.00
Commelina virginica			41.2	1.48							0.00
Cornus amomum									7.7	0.45	0.45
Cuscuta gronovii	10.1	1.0						1.07			3.05
Cyperus esculentus			13.6					0.69			0.69
Cyperus odoratus				0.55							0.00
Eleocharis ovata			26.2	0.89							0.00
Elymus villosus	24.1	0.94									1.88
Galium tinctorium		0.9				0.22	19	1.48		0.62	4.10
Hibiscus moscheutos	34	2.3						1.13			5.77
Impatiens capensis	10.7	1.0				0.38		0.46		0.32	3.14
Iris pseudacorus									25.7	1.48	1.48
Juncus effusus							34.7	2.33		0.57	2.90
Justicia americana									17.3	0.63	0.63
Leersia oryzoides		2.7		1.07	27.2	2.25		5.32		0.32	13.27
Leersia virginica		0.3									0.64
Lemna minor/Spirodela polyrrhiza					10.7	0.38					0.38
Ludwigia palustris			16.9	0.31							0.00
Lindernia dubia				0.39	24.8	0.95					0.95
Myriophyllum spicatum		0.3									0.64
Najas minor		0.5									1.04
Nelumbo lutea							5.2	0.46			0.46
Nelumbo nucifera			18.5	0.90							0.00
Onoclea sensibilis						0.17	25.7	2.40			2.57
Dichanthelium clandestinum	15.1	0.5									1.00

Table 3. continued

	Chandler's Run		Chickamauga Creek		Crab Creek		Ginat's Run		Teen's Run		Regional
Species	**IV**	**RIV**	**IV**	**RIV**	**IV**	**RIV**	**IV**	**RIV**	**IV**	**RIV**	**RIV**
Persicaria pensylvanica			21.5	0.33							0.00
Persicaria punctata		2.2	38.5	2.03		0.64				0.77	5.81
Persicaria sagittata	36	3.7		0.77		0.65		2.40		0.54	10.93
Sagittaria latifolia		0.5		1.57		1.27		3.14	25.5	3.73	9.14
Saururus cernuus				0.42							0.00
Schoenoplectus tabernaemontani				0.56		0.16		0.75			0.91
Scirpus cyperinus								0.66			0.66
Sparganium eurycarpum		2.4			24.8	2.75		2.90		5.00	15.39
Typha latifolia							21.2	1.17		0.36	1.53
Xanthium strumarium			26.2	0.50							0.00
Subtotal:		19.22		14.57		11.62		26.36		16.30	92.72
Other Taxa (65 species):		2.18		4.11		0.96		1.18		4.00	7.28
Total:		21.40		18.18		12.58		27.54		20.30	60.42

TABLE 4. Significant ($p < 0.001$) indicator values (IV) and relative importance values (RIV) of cluster analysis defined herbaceous plant communities among embayment sites. Indicator

	Community											
	A		B		C		D		E		F	
Taxa	**IV**	**RIV**	**IV**	**RIV**	**IV**	**RIV**	**IV**	**RIV**	**IV**	**RIV**	**IV**	**RIV**
Ammannia coccinea											15.5	0.27
Apios americana							23.9	0.30				
Arthraxon hispidus							14.7	0.24				
Asclepias incarnata	11.9	0.12										
Boehmeria cylindrica		0.08					26.4	0.59		0.06		
Carex stipata					18.2	0.05						
Carex tribuloides							61.0	1.43		0.06		
Commelina communis	28.4	0.24										
Commelina virginica							60.0	1.41				
Cornus amomum									42.1	0.45		
Cuscuta gronovii		0.19	22.2	1.21		0.11		0.26				
Cyperus odoratus											18.9	0.80
Elymus villosus		0.05	17.5	0.60								
Galium tinctorium		0.23		0.47		0.16				0.11		
Hibiscus moscheutos		0.22	39.8	1.08		0.08						0.30
Impatiens capensis		0.05		0.42						0.11	16.7	0.89
Iris pseudacorus						0.03			96.9	1.28		
Juncus effusus										0.10		0.46
Justicia americana												
Laportea canadensis			13.9	0.25								
Leersia oryzoides		0.13		1.38		0.12		0.54				0.93
Lindernia dubia											16.7	0.29
Ludwigia palustris												
Lysimachia nummularia									18.5	0.19		
Myriophyllum spicatum												
Najas minor												
Nelumbo lutea												
Nelumbo nucifera											20.7	0.90
Onoclea sensibilis				0.52	75.0	0.72		0.17				0.29
Dichanthelium clandestinum		0.05	14.0	0.37								
Persicaria hydropiperoides	25.8	0.19										
Persicaria pensylvanica							25.4	0.28				
Persicaria punctata	55.5	1.31		0.79				1.03				0.55
Persicaria sagittata		0.70	38.3	3.20		0.29		0.92		0.09		0.50
Sagittaria latifolia		0.09		0.57		0.15		1.61		0.37		0.65
Schoenoplectus tabernaemontani		0.13										0.42
Scirpus cyperinus								0.24				0.31
Solanum carolinense	12.5	0.13										
Sparganium eurycarpum		0.31		1.08		0.27				0.19		
Typha latifolia				0.17	16.7	0.15		0.15		0.06		
Xanthium strumarium							40.0	0.47				
Subtotal:		4.22		12.11		2.13		9.64		3.07		7.56
Other Taxa (n = 74):		0.36		2.55		0.49		1.96		0.67		5.51
Total:		4.58		14.66		2.62		11.60		3.74		13.072

values in bold represent species that were faithful to a particular community and RIV bold values are those species that contributed to 5% or more to that community type.

	Community											
	G		H		I		J		K		L	
Taxa	IV	RIV	IV	RIV	IV	RIV	IV	RIV	IV	RIV	IV	RIV
Ammannia coccinea												
Apios americana												
Arthraxon hispidus												
Asclepias incarnata												
Boehmeria cylindrica										0.52		
Carex stipata												
Carex tribuloides								0.11				
Commelina communis												
Commelina virginica												
Cornus amomum												
Cuscuta gronovii								0.07		0.33		0.27
Cyperus odoratus												
Elymus villosus												
Galium tinctorium						0.02		0.22		0.82		0.90
Hibiscus moscheutos								0.14		0.24		0.51
Impatiens capensis								0.08		0.40		0.19
Iris pseudacorus										0.19		
Juncus effusus\							83.4	1.52				0.80
Justicia americana							15.3	0.63		0.59		
Laportea canadensis												
Leersia oryzoides						0.32		0.39		0.50	53.9	7.29
Lindernia dubia												
Ludwigia palustris					96.4	0.89				0.21		
Lysimachia nummularia												
Myriophyllum spicatum	68.0	0.29		0.15								
Najas minor	100.0	0.52										
Nelumbo lutea			99.8	0.43								
Nelumbo nucifera												
Onoclea sensibilis					0.0			0.23				0.61
Dichanthelium clandestinum												
Persicaria hydropiperoides												
Persicaria pensylvanica												
Persicaria punctata						0.13				1.24		0.63
Persicaria sagittata								0.22		0.87		1.26
Sagittaria latifolia								0.29	24.4	4.29		2.22
Schoenoplectus tabernaemontani							25.4	0.46		0.31		0.17
Scirpus cyperinus												0.47
Solanum carolinense												
Sparganium eurycarpum								0.33	53.8	7.99		2.69
Typha latifolia\								0.12		0.38		0.54
Xanthium strumarium												
Subtotal:		0.81		0.58		1.36		4.81		18.88		18.55
Other Taxa (n = 74):		0.02		0.00		0.35		0.08		1.92		2.37
Total:		0.83		0.58		1.71		4.89		20.80		20.92

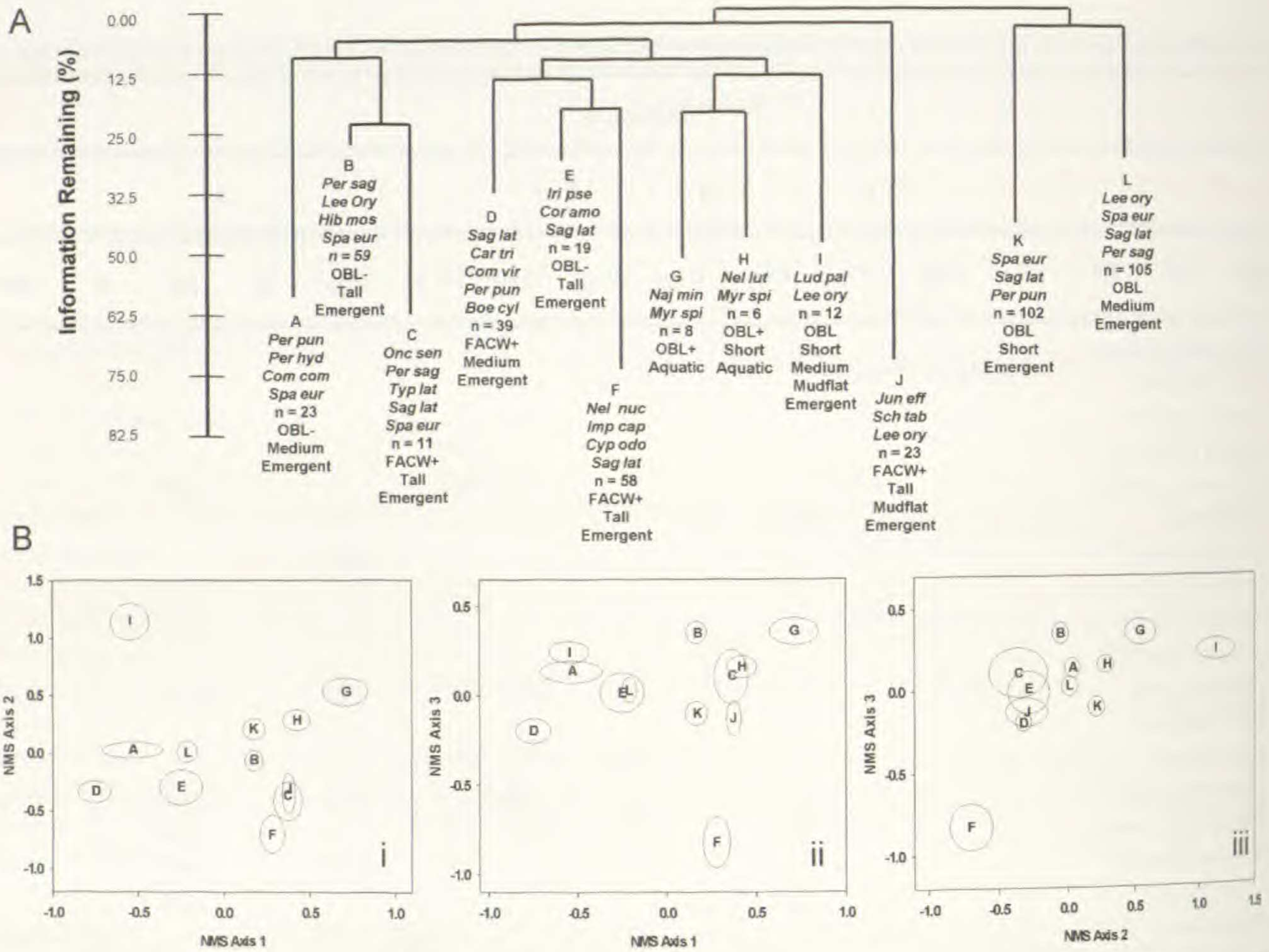

Fig. 4. A. Dendrogram of the results of hierarchical, agglomerative cluster analysis, grouping 465 1 m² quadrats into twelve community types, named for the species with the highest relative importance value and indicator value. The dendrogram is scaled by Wishart's (1969) objective function, expressed as the percentage of information remaining at each level of grouping (McCune & Grace 2002). B. Non-metric multidimensional scaling of plant community species cover and sample ordination axes scores (mean ± 1 standard error).

9) and Crab Creek (n = 1). The tall obligate- emergent community was characterized by *Hibiscus moscheutos* and *Persicaria sagittata* were the indicator and dominant species with subdominants of *Leersia oryzoides* and *Sparganium eurycarpum* (Table 4, Fig. 4, community B). This community occurred at Chandler's Run (n = 43), Ginat's Run (n = 14) and Crab Creek (n = 2). The other obligate- tall emergent community (Table 4, Fig. 4, community E) was characterized by a non-native species, *Iris pseudacorus*, and a shrub or understory tree species, *Cornus amomum* with limited contributions of *Sagittaria latifolia*. This community was distributed primarily at Teen's Run (n = 18) with one sample found at Chandler's Run.

There were three obligate emergent communities defined among embayments. *Ludwigia palustris* was the dominant and indicator species for a short or mudflat emergent community (Table 4, Fig. 4, community I) with limited contributions of *Leersia oryzoides* and minor contributions of *Persicaria punctata* was defined for Chickamauga Creek (n = 2) and Crab Creek (n = 10). The short emergent community (Table 4, Fig. 4, community K) was dominated by *Sparganium eurycarpum* and its subdominant of *Sagittaria* latifolia with limited contribution of *Persicaria punctata*. Both of the former two species were indicators. Although Teen's Run had the most number of samples (n = 61), this community was also distributed among three other embayment sites and include Chandler's Run (n = 10), Crab Creek (n = 20), Ginat's Run (n = 11). The medium obligate emergent community (Table 4, Fig. 4, community L) was dominated by the only indicator species, *Leersia oryzoides*, with limited contributions of *Sparganium eurycarpum*, *Sagittaria latifolia*, and *Persicaria sagittata*. This community was primarily at Ginat's Run (n = 59) but was found among all sites. Although Chandler's

Run and Crab Creek had nearly equal numbers of samples (20 and 21, respectively), both Chickamauga Creek and Teen's Run sample numbers were small (1 and 4, respectively).

Four Facultative Wet+ communities were comprised of an equal number of tall and medium height emergent species. Two indicator species (*Carex tribuloides* and *Commelina virginica*) shared dominance at one of the medium emergent community (Table 4, Fig. 4, community D) and was distributed among Chickamauga Creek (n = 31), Ginat's Run (n = 6) and Teen's Run (n = 2). *Onoclea sensibilis* was the dominant and indicator species at a tall facultative wet+ emergent community (Table 4, Fig. 4, community C), *Carex stipata* and *Typha latifolia* L. (broad-leaved cat-tail) were also indicators. The latter community was found at Crab Creek (n = 10) and Chickamauga Creek (n = 2). *Leersia oryzoides*, *Nelumbo nucifera*, and *Impatiens capensis* were co-dominants and indicators at a tall facultative wet+ emergent community (Table 4, Fig. 4, community F) that was distributed among four sites: Chandler's Run (n = 9), Chickamauga Creek (n = 22), Ginat's Run (n = 13) and Teen's Run (n = 14). The other tall emergent community (Table 4, Fig. 4, community J) was dominated by *Juncus effusus* with limited a contribution of *Schoenoplectus tabernaemontani* (C.C. Gmelin) Palla (soft-stem bulrush). Both species along with *Justicia americana* were indicator species but the latter species was of minor importance to the overall community and occurred primarily at Teen's Run. This community (J) was characteristic of Ginat's Run (n = 17), but was also found at Teen's Run (n = 4), Chandler's Run (n = 1) and Crab Creek (n = 1). Non-metric Multi-dimensional Scaling (see below) show that the ordination procedure separated the cluster analysis defined herbaceous plant communities (Fig. 4B i, ii, iii) among three axes.

Herbaceous Community Composition and Potential Gradients

Non-metric multi-dimensional scaling (NMS) was used to explore the relationship of herbaceous species and samples among embayment sites and cluster analysis defined groups for each site. The NMS resulted in three axes or dimensions with the number of runs for the Monte-Carlo simulations were 150. The final stress was 11.6. Ecological community data often have final stress values between 10 and 20%. Values in the lower half of this range represent reliable solutions (McCune & Grace 2002). The total proportion of variance represented by NMS was 84.6%. The first axis accounted for majority of the variation (64.0%), the second axis accounted for 13.6% and the third accounted for 7.1%. The NMS ordination axis 1 (Fig. 5i) separated Chickamauga Creek, Crab Creek and Ginat's Run from Chandler's Run and Teen's Run. The first axis was positively associated with embayment age ($\tau = 0.58$), non-native species ($\tau = 0.42$) and negatively associated with river kilometer ($\tau = -0.55$) and a weak negative association with Coefficient of Conservatism (CC) ($\tau = -0.22$), richness ($\tau = -0.09$) and diversity ($\tau = -0.11$). The MRPP for the testing of differences in herbaceous species cover and sample data were weakly defined among age of embayment sites ($T = -60.18$, $\delta = 0.47$, $A = 0.21$, $P < 0.01$). The second axis separated Chandler's Run and Teen's Run from the other sites (Fig. 5ii). This axis was positively associated with Wetland Indicator Status Values ($\tau = 0.45$). Richness ($\tau = -0.41$) and diversity ($\tau = -0.36$) had a negative association with the second axis. The third axis separated all sites except for Chickamauga Creek and Crab Creek (Fig. 5iii) and was positively associated with embayment site ($\tau = 0.64$), embayment size ($\tau = 0.27$) and river kilometer ($\tau = 0.15$). Species cover ($\tau = -0.18$), richness ($\tau = 0.16$), diversity ($\tau = -0.12$), CC ($\tau = -0.12$) and Wetland Indicator Status Value ($\tau = -0.09$) were negatively associated with this axis. The MRPP for the testing of differences in herbaceous species cover and sample data were moderately defined according to river kilometer (site) among embayment sites ($T = -79.83$, $\delta =$ of 0.41, $A = 0.18$, $P < 0.01$).

DISCUSSION

Floodplains have been traditionally 'hotspots' of community and species diversity (Gopal & Junk 2000) due to the characteristics of the flood pulse processes (Junk & Wantzen 2004; Junk 1997; Middleton 2002). In addition, local species richness and diversity in small wetland areas are typically high (Flinn et al. 2008) because of the diversity of habitats along hydrological gradients that result in defined niches (Silvertown et al. 1999; Silvertown et al. 2001). There are limitations of the current study and include the inferred environmental gradients from floristic quality index values (Wetland Indicator Status and Coefficient of Conservatism), limited distribution of study sites along the Ohio River, and pseudoreplication (Hurlbert

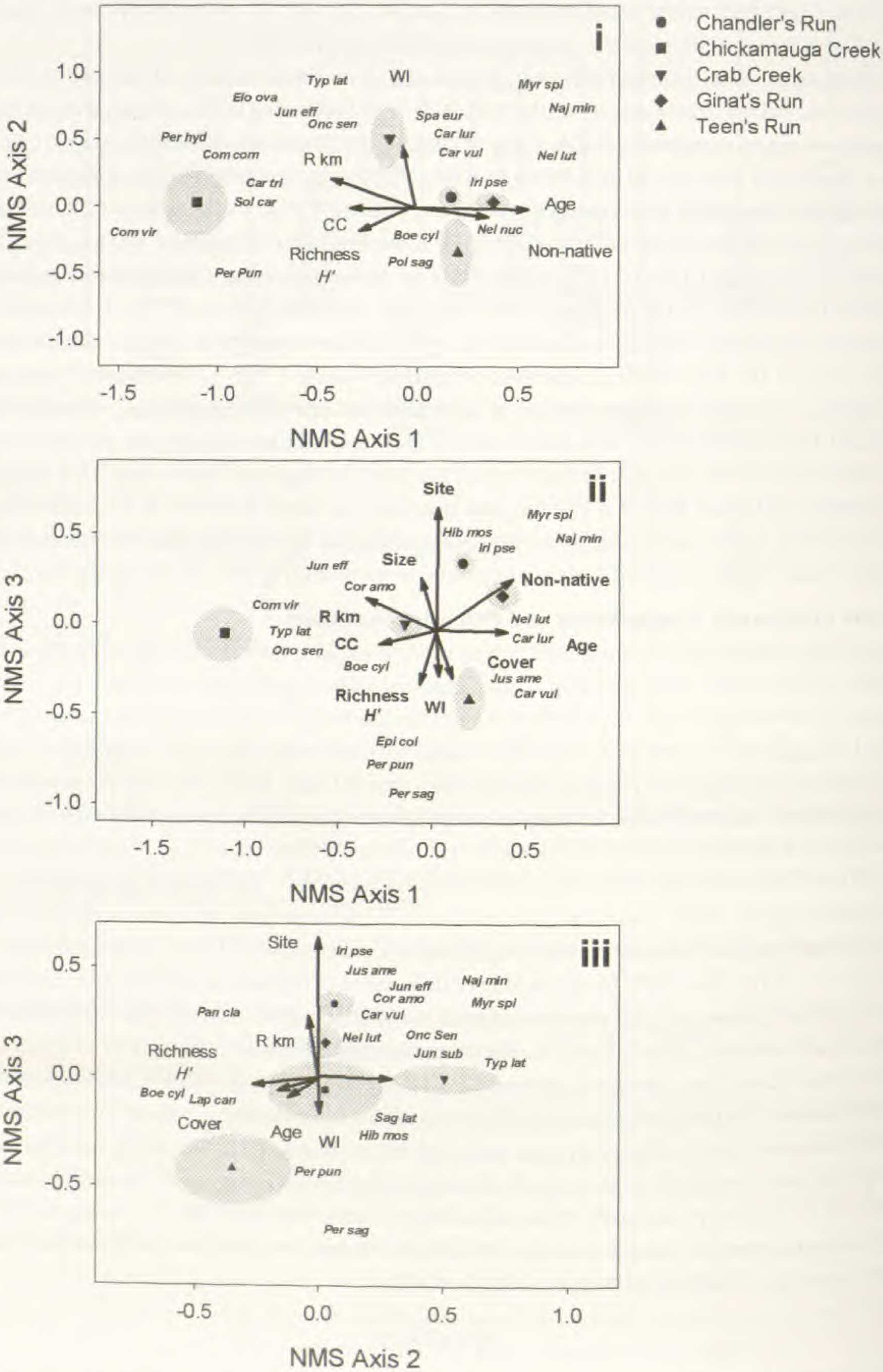

Fig. 5. Samples and herbaceous species non-metric multi-dimensional scaling (NMS) ordination bi-plots of plant species cover data among embayment sites. NMS ordination of plant species cover values and environmental data from 465 1 m^2 quadrats composition surveyed from five embayment sites. Joint bi-plots showing relationships between ordination axes and individual plant species, river location (R km), age, richness, diversity (H'), Coefficient of Conservatism values (CC), wetland indicator probability values (WI), total cover values, non-native plant species cover, and site. Plant species cover values associated with each axis are also given and consists of the first three letters of the genus and specific epithet. The angles and lengths of the radiating lines indicate the direction and strength of the association, based on Kendall's correlations (Zar 2010) between axis scores and values of plant species cover and environmental variables. The bi-plots only shows correlations of $|r| > 0.15$.

1984). However, the authors feel that this study provides baseline data, plant community classification, potential gradients, and species information for future work along the Ohio River and other major navigable rivers where embayments may have been formed. We document species composition, structure, diversity, plant communities and potential gradients of embayment wetlands that occur along the mid- to mid-upper Ohio River floodplain.

There were 257 species of vascular plants recorded from approximately 27 ha of embayment habitat. Our results are in accord with other wetland studies of the region. For example, Stark (1993) reported 335 species from Green Bottom Wildlife Management Area while West and Evans (1982) recorded 252 vascular plant species along the Kanawha River. Both of the latter studies encompassed a combined study area of approximately 400 ha. There were 360 species recorded in a classical study of the floodplain vegetation and environment along the Raritan River, NJ, but encompassed the entire floodplain from terrace to terrace (Wistendahl 1958). In another example, a total of 629 vascular plants were recorded along a 660 mile stretch of two rivers in a study of the plant communities, vegetation and environmental characteristics of the Wabash and Tippecanoe Rivers by Lindsey et al. (1961).

Sixty-four of the 257 species observed (34.6%) occurred at all embayment sites. However, these species are common and widely distributed elements of the region. The remaining 192 species have a more limited distribution with 36 (5.3%) at four sites, and 23 (9.0%) at three sites. Of those species most restricted in distribution, forty-five taxa (17.4%) occurred at two sites, and the largest number of taxa, 90 (34.6%), were limited to a single site.

Embayment sites capture approximately 25% of the species that are common elements of the floodplain. However, more than half the number of species encountered across the sample area was restricted to one or two sites. This suggests that these wetlands have common elements at large broad scales with distinct elements at small scales.

The woody species that defined the embayment bottomland hardwood forests were common elements of the Ohio River riparian zone. The *Acer saccharinum*, *Fraxinus pennsylvanicum*, *Platanus occidentalis*, and *Salix nigra* community dominated the forests and our results (Table 1) are consistent with other riparian studies along the Ohio River floodplain and other large rivers (Clagg & Mills 1978; Evans 1980, 1977a, 1977b; Furry & Evans 1979; Koryak 1978; Liu 1991; Stark 1993). The forests encountered in this study would be considered an *Acer saccharinum* forest alliance as defined by The Nature conservancy (Weakley et al. 1996). Ginat's and Teen's Run embayment sites had the greatest tree species diversity among all sites and is probably due to the degree of disturbance or lack of it. Ginat's Run forest is secluded from surrounding agriculture fields and development and has had minimal disturbance while Teen's Run site has had significant amount of disturbance in the past with numerous homesteads and agriculture. In addition, Ginat's Run's forest were more even-aged than the remaining embayment sites that were characterized by high recruitment of *Acer saccharinum* as indicated by the density of trees in the smallest size class (Ely 1993).

Although *Acer saccharinum* was the dominant tree species, it had a limited distribution among the shrub and sapling layer (Table 2). *Alnus serrulata* was the dominant shrub at Ginat's Run with very limited contributions of other species including *Acer saccharinum*. *Cornus amomum* and *Salix nigra* were co-dominants with *Acer saccharinum* at Teen's Run. *Acer saccharinum* along with *Lindera benzoin* were sub-dominants to *Fraxinus pennsylvanicum* at Crab Creek. The shrub alliances (Weakley et al. 1996) among embayments were more diverse than the tree layer. Chickamauga Creek's shrub community would be considered a *Cephalanthus occidentalis* shrub alliance while Ginat's Run would be an *Alnus serrulata* alliance. Chandler's Run shrub layer would be mix of *Alnus serrulata* and *Salix nigra* and the shrub community at Crab Creek would be considered a *Lindera benzoin* mixed alliance with *Betula nigra* and *Asimina triloba* (L.) Dunal (pawpaw). Finally, Teen's Run alliance is characterized by *Cornus amomum*, a Midwestern element.

At the local scale (embayment site) herbaceous species composition, richness and diversity show that there were differences among sites (Fig. 3i, ii). In addition, sites with significantly higher species richness and diversity tended to have the lowest wetland indicator and coefficient of conservatism values (Fig. 3i, ii, iv, v). Two embayment sites have non-native species cover values approaching 20% while the remaining sites are below 10% (Fig. 3vi). Chickamauga Creek and Teen's Run embayment sites would be considered the most disturbed of the five sites. Chickamauga Creek site is surrounded by the city of Gallipolis, Ohio, and adds to the level of disturbance along the edge of that site. Teen's Run while in a remote location consists of former farmsteads and agricultural fields. There were two non-native species that were important components of several communities at Chickamauga Creek and Teen's Run, *Nelumbo nucifera* and *Iris pseudacorus* L. (yellow flag), respectively, both species were indicators and important component of the plant communities (Tables 3 and 4; Fig. 4) *Nelumbo nucifera* was previously reported by M. L. Roberts in 1973 (Cusick & Silberhorn 1977). Another non-native species, *Amaranthus cruentus* L. (purple amaranth), was also recorded for the second time from this site; however, this taxon is cultivated as an ornamental and often escapes cultivation. Lopez and Fennessy (2002) found that the Coefficient of Conservatism values tend to be low in Ohio wetlands that are surrounded by agriculture fields and urban centers. This is consistent with Cohen et al. (2004) findings of the effect of landscape development of intensity on Coefficient of Conservatism values in depressional marshes of Florida. Floodplains and riparian zones are generally vulnerable to non-native and invasive species under normal conditions due to the dynamic nature of riparian systems but more so under altered hydrological conditions (Nilsson & Berggren 2000).

The NMS ordination of species and samples were associated with age and river kilometer (Fig. 4i; axis 1), wet gradient or water depth (Fig. 4i; axis 2, as indicated by wetland indicator status values and distance of sample plots from the edge of the embayment to open water), size and site (Fig. 4ii, iii; axis 3). Non-native species cover, total cover, Coefficient of Conservatism, Richness, and Diversity were associated moderately to the ordination scores. Furthermore, MRPP was able to detect differences in species and species cover values among embayment sites, age, and river kilometer location. These results indicate that embayment location, size, and age are factors that determine the distribution and abundance of plant species.

Of the herbaceous plant communities we defined, there were four groups that were distinct and had limited integration with the other herbaceous communities. These include two aquatic and two emergent communities. Two communities of lotus (*Nelumbo nucifera* and *N. lutea*) are considered distinct and unique for this region of the Ohio River (Table 4 and Fig. 4). The *Nelumbo lutea* community was an important component of the emergent-submerged aquatic community at Ginat's Run and was unexpected for the unglaciated region of the state (Alison Cusick, pers. comm.; Cusick & Silberhorn 1977). The tall emergent community at Chickamauga Creek is the only known community along the Ohio River that has a dominant and indicator species of *Nelumbo nucifera*, an introduced taxon. The remaining eight defined communities are composed of common elements of the region and are not unexpected. Communities are typically composed of species that are distributed along an integrated series of aquatic, wetland and upland habitats and are consistent with riparian forests of the Allegheny Plateau, Pennsylvania (Williams et al. 1999).

The purpose of this study was to classify and describe plant communities of selected embayment sites along the mid to mid-upper Ohio River floodplain. We classified five *Acer saccharinum* bottomland hardwood forest communities, five sapling and shrub and twelve herbaceous plant communities. Herbaceous plant species and communities were further analyzed through the use of indirect ordination procedures and non-parametric tests in order to describe potential environmental gradients. We also have provided baseline information on embayment plant communities along this stretch of the Ohio River that allows for future comparative studies. Future embayment work needed includes surveys of the flora, fauna (all types), classification, characterization of nutrient cycling, productivity analyses, soil classification, successional relationships and hydrological surveys.

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